BIONA-C Inflight Technology Demonstration

John W. Hines

The Biological Ion Analysis in the Cell Culture Module (BIONA-C) flew onboard the space transport system (STS-93) (July 23–27, 1999) as a technology demonstration of the capability to monitor and control pH measurements during spaceflight. Working with the U. S. Army Medical Research and Material Command (USAMRMC) and in close collaboration with the Cell Culture Module (CCM) team from the Walter Reed Army Institute of Research (WRAIR), Ames Research Center (ARC) developed BIONA-C as an autonomous monitoring and control system for a spaceborne hollow-fiber bioreactor experiment. BIONA-C monitored the pH and temperature of circulating media and controlled the collection of samples and addition of nutrients for the cells growing in the ARC Rail, shown in the figure.

The BIONA-C Rail contains four independent fluid paths that circulate media to support cell growth. In each path, media flows through a separate bioreactor where fluids can transfer across a permeable membrane to the cell culture, but cells cannot enter the fluid path. In two of the fluid paths the sensors are located directly in the circulating media ("online"), taking continuous pH measurements. Calibration of the online sensors occurs on Earth before and after the experiment. In the other two paths a precision pump periodically transfers media samples from the circulating media path to the sensors. This "offline" configuration allows the sensors to be calibrated inflight between each sample reading.

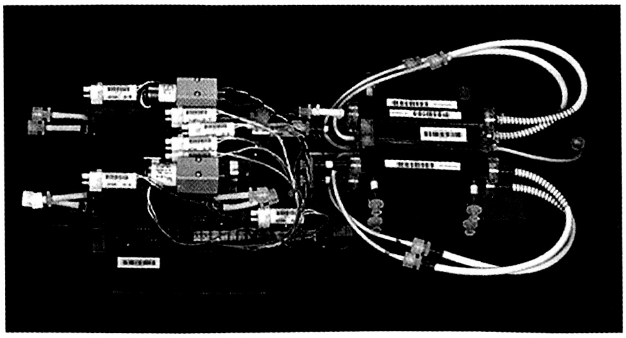

Fig. 1. BIONA-C Rail.

The sensor arrays are sealed and electron beam sterilized. Sterile practices are used during all experimental preparation, rail priming, and sensor calibration. When operating, the rail maintains the temperature of the bioreactor and oxygenator assembly at 37 degrees Celsius.

The capability to monitor and control bioprocess experiments gives BIONA-C enormous potential in the areas of space genomics, evolutionary biology, and astrobiology. The system has applications in cell growth and plant growth facilities in space. It can also be utilized in developing long-term, closed human habitats for future Mars exploration. The BIONA-C technology can be adapted to perform in measurement stations that search for life in extreme environments such as ocean floor hydrothermal vents.

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Solid-State Compressors for Mars ISRU

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One important way to extend the science and exploration capabilities of Mars surface missions is to use the readily available Mars atmosphere as a resource to provide critical supplies that would otherwise limit the mission or make it too expensive. Compressed and purified gases, oxygen, important chemicals, and even rover and rocket fuel can be manufactured largely from Martian atmospheric gases, saving the costs of their transport from Earth and ensuring that a mission doesn't end when it "runs out of gas." These techniques are examples of a popular mission strategy that is generally termed "in situ resource utilization," or ISRU.

The Mars atmosphere consists mostly of carbon dioxide, with relatively small amounts of nitrogen and other gases. At about 0.7 kiloPascals (0.1 pounds per square inch) total pressure, the mixed gases are too thin to be useful directly, so the atmospheric constituents must be separated from each other and compressed. Ames Research Center (ARC) is developing solid-state adsorption compression and separation technology to acquire the Mars atmospheric constituents and make them available for downstream processing or direct use.

The ARC adsorption compression technology uses a zeolite adsorbent bed that can adsorb large quantities of carbon dioxide at the ambient temperature and pressure of the Mars surface. Its capacity for the other Mars gases is much lower; these gases are drawn through the adsorbent and stored in a second bed for later processing. When the adsorbent is saturated with carbon dioxide, the compressor is isolated and warmed. Carbon dioxide then evolves from the sorbent, resulting in a rapid pressure increase inside the compressor. When the pressure reaches a desired level, the carbon dioxide can be drawn off. The supplied pressure is easily regulated by controlling the power level of the compressor heater. When the supply of carbon dioxide is exhausted, the bed is allowed to cool and to adsorb another load of carbon dioxide. The cycle can be repeated indefinitely.

The first uses for this adsorption compression technology will be on robotic exploration missions. A prototype for adsorption compression at this mission scale is shown in the figure. The one-kilogram device shown has been tested successfully under simulated Mars surface conditions, under which it produces approximately 15 grams of carbon dioxide per day at a pressure of 120 kiloPascals (17.4 pounds per square inch), and requires an average of 7 watts of power during 5 hours of production. Larger-scale productions will be more economical as the fraction of structural mass decreases, with an anticipated daily production level of about 250 grams carbon dioxide per kilogram of compressor mass.

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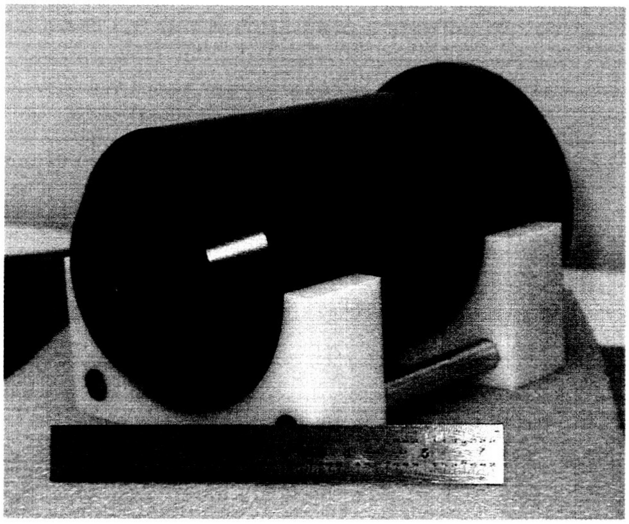

Fig. 1. Prototype solid-state adsorption compressor for Mars carbon dioxide, 15 grams/day scale. A nitrogen/argon mixture is produced as a byproduct.

Dynamic Modeling of Life Support Systems

Cory Finn and Harry Jones

Dynamic system models have been developed that track the flow of material through a regenerative life support system over time periods of months to years. These models are being used to help evaluate system design and operation issues for the Advanced Life Support Systems Integrated Test Bed (ALSSITB). The model captures the main flow stream characteristics associated with atmosphere regeneration, water recovery, crop growth, food processing, and waste processing. The system simulation quantifies the variations in stream flow rates and subsystem processing rates so that estimates can be made on buffer requirements for various system configurations and design options. It is also being used to investigate scheduling, operations, and control issues.

Dynamic modeling is an important tool for developing robust system designs. Static or steady-state models are often used to obtain estimates on nominal processor flow rates and resupply requirements. However, more detailed system design